CHAPTER 22 (Odd)

1. a. $E_\phi = E_L/\sqrt{3} = 208 \text{ V}/1.732 = \mathbf{120.1\ V}$ b. $V_\phi = E_\phi = \mathbf{120.1\ V}$

   c. $I_\phi = \dfrac{V_\phi}{R_\phi} = \dfrac{120.1\text{ V}}{10\ \Omega} = \mathbf{12.01\ A}$ d. $I_L = I_\phi = \mathbf{12.01\ A}$

3. a. $E_\phi = \mathbf{120.1\ V}$ b. $V_\phi = \mathbf{120.1\ V}$

   c. $Z_\phi = (10\ \Omega \angle 0°) \| (10\ \Omega \angle -90°) = 7.071\ \Omega \angle -45°$

   $I_\phi = \dfrac{V_\phi}{Z_\phi} = \dfrac{120.1\text{ V}}{7.071\ \Omega} = \mathbf{16.98\ A}$

   d. $I_L = \mathbf{16.98\ A}$

5. a. $\theta_2 = \mathbf{-120°}$, $\theta_3 = \mathbf{+120°}$

   b. $\mathbf{V}_{an} = \mathbf{120\ V \angle 0°}$, $\mathbf{V}_{bn} = \mathbf{120\ V \angle -120°}$, $\mathbf{V}_{cn} = \mathbf{120\ V \angle 120°}$

   c. $\mathbf{Z}_\phi = 9\ \Omega + j12\ \Omega = 15\ \Omega \angle 53.13°$

   $\mathbf{I}_{an} = \dfrac{120\text{ V} \angle 0°}{15\ \Omega \angle 53.13°} = \mathbf{8\ A \angle -53.13°}$, $\mathbf{I}_{bn} = \dfrac{120\text{ V} \angle -120°}{15\ \Omega \angle 53.13°} = \mathbf{8\ A \angle -173.13°}$

   $\mathbf{I}_{cn} = \dfrac{120\text{ V} \angle 120°}{15\ \Omega \angle 53.13°} = \mathbf{8\ A \angle 66.87°}$

   e. $I_L = I_\phi = \mathbf{8\ A}$ f. $E_L = \sqrt{3}\,E_\phi = (1.732)(120\text{ V}) = \mathbf{207.85\ V}$

7. $V_\phi = V_{an} = V_{bn} = V_{cn} = \dfrac{V_L}{\sqrt{3}} = \dfrac{220\text{ V}}{1.732} = \mathbf{127.0\ V}$

   $\mathbf{Z}_\phi = 10\ \Omega - j10\ \Omega = 14.42\ \Omega \angle -45°$

   $I_\phi = I_{an} = I_{bn} = I_{cn} = \dfrac{V_\phi}{Z_\phi} = \dfrac{127\text{ V}}{14.142\ \Omega} = \mathbf{8.98\ A}$

   $I_L = I_{Aa} = I_{Bb} = I_{Cc} = I_\phi = \mathbf{8.98\ A}$

9. a. $\mathbf{E}_{AN} = \dfrac{22\text{ kV}}{\sqrt{3}} \angle -30° = \mathbf{12.7\ kV \angle -30°}$

   $\mathbf{E}_{BN} = \dfrac{22\text{ kV}}{\sqrt{3}} \angle -150° = \mathbf{12.7\ kV \angle -150°}$

   $\mathbf{E}_{CN} = \dfrac{22\text{ kV}}{\sqrt{3}} \angle 90° = \mathbf{12.7\ kV \angle 90°}$

b, c. $\mathbf{I}_{Aa} = \mathbf{I}_{an} = \dfrac{\mathbf{E}_{AN}}{\mathbf{Z}_{AN}} = \dfrac{12.7 \text{ kV} \angle -30°}{(30\ \Omega + j40\ \Omega) + (0.4\text{ k}\Omega + j1\text{ k}\Omega)}$

$= \dfrac{12.7 \text{ kV} \angle -30°}{430\ \Omega + j1040\ \Omega} = \dfrac{12.7 \text{ kV} \angle -30°}{1125.39\ \Omega \angle 67.54°}$

$= \mathbf{11.285\ A \angle -97.54°}$

$\mathbf{I}_{Bb} = \mathbf{I}_{bn} = \dfrac{\mathbf{E}_{BN}}{\mathbf{Z}_{BN}} = \dfrac{12.7 \text{ kV} \angle -150°}{1125.39\ \Omega \angle 67.54°} = \mathbf{11.285\ A \angle -217.54°}$

$\mathbf{I}_{Cc} = \mathbf{I}_{cn} = \dfrac{\mathbf{E}_{CN}}{\mathbf{Z}_{CN}} = \dfrac{12.7 \text{ kV} \angle 90°}{1125.39\ \Omega \angle 67.54°} = \mathbf{11.285\ A \angle 22.46°}$

d. $\mathbf{V}_{an} = \mathbf{I}_{an}\mathbf{Z}_{an} = (11.285\text{ A} \angle -97.54°)(400 + j1000)$

$= (11.285\text{ A} \angle -97.54°)(1077.03\ \Omega \angle 68.2°)$

$= \mathbf{12{,}154.28\ V \angle -29.34°}$

$\mathbf{V}_{bn} = \mathbf{I}_{bn}\mathbf{Z}_{bn} = (11.285\text{ A} \angle -217.54°)(1077.03 \angle 68.2°)$

$= \mathbf{12{,}154.28\ V \angle -149.34°}$

$\mathbf{V}_{cn} = \mathbf{I}_{cn}\mathbf{Z}_{cn} = (11.285\text{ A} \angle 22.46°)(1077.03 \angle 68.2°)$

$= \mathbf{12{,}154.28\ V \angle 90.66°}$

11. a. $E_\phi = E_L/\sqrt{3} = 208\text{ V}/1.732 = \mathbf{120.1\ V}$ b. $V_\phi = E_L = \mathbf{208\ V}$

c. $\mathbf{Z}_\phi = 6.8\ \Omega + j14\ \Omega = 15.564\ \Omega \angle 64.09°$

$I_\phi = \dfrac{V_\phi}{Z_\phi} = \dfrac{208\text{ V}}{15.564\ \Omega} = \mathbf{13.364\ A}$

d. $I_L = \sqrt{3}\, I_\phi = (1.732)(13.364\text{ A}) = \mathbf{23.15\ A}$

13. a. $\theta_2 = \mathbf{-120°},\ \theta_3 = \mathbf{+120°}$

b. $\mathbf{V}_{ab} = \mathbf{208\ V \angle 0°},\ \mathbf{V}_{bc} = \mathbf{208\ V \angle -120°},\ \mathbf{V}_{ca} = \mathbf{208\ V \angle 120°}$

c. —

d. $\mathbf{I}_{ab} = \dfrac{\mathbf{V}_{ab}}{\mathbf{Z}_{ab}} = \dfrac{208\text{ V} \angle 0°}{22\ \Omega \angle 0°} = \mathbf{9.455\ A \angle 0°}$

$\mathbf{I}_{bc} = \dfrac{\mathbf{V}_{bc}}{\mathbf{Z}_{bc}} = \dfrac{208\text{ V} \angle -120°}{22\ \Omega \angle 0°} = \mathbf{9.455\ A \angle -120°}$

$\mathbf{I}_{ca} = \dfrac{\mathbf{V}_{ca}}{\mathbf{Z}_{ca}} = \dfrac{208\text{ V} \angle 120°}{22\ \Omega \angle 0°} = \mathbf{9.455\ A \angle 120°}$

e. $I_L = \sqrt{3}\, I_\phi = (1.732)(9.455\text{ A}) = \mathbf{16.376\ A}$

f. $E_\phi = E_L/\sqrt{3} = 208\text{ V}/1.732 = \mathbf{120.1\ V}$

15. a, b. The same as problem 12. c. —

d. $\mathbf{Z}_\phi = 3\ \Omega\ \angle 0° \| 4\ \Omega\ \angle 90° = 2.4\ \Omega\ \angle 36.87°$

$$\mathbf{I}_{ab} = \frac{\mathbf{V}_{ab}}{\mathbf{Z}_{ab}} = \frac{208\text{ V }\angle 0°}{2.4\ \Omega\ \angle 36.87°} = \mathbf{86.67\text{ A }\angle -36.87°}$$

$$\mathbf{I}_{bc} = \frac{\mathbf{V}_{bc}}{\mathbf{Z}_{bc}} = \frac{208\text{ V }\angle -120°}{2.4\ \Omega\ \angle 36.87°} = \mathbf{86.67\text{ A }\angle -156.87°}$$

$$\mathbf{I}_{ca} = \frac{\mathbf{V}_{ca}}{\mathbf{Z}_{ca}} = \frac{208\text{ V }\angle 120°}{2.4\ \Omega\ \angle 36.87°} = \mathbf{86.67\text{ A }\angle 83.13°}$$

e. $\mathbf{I}_L = \sqrt{3}\, I_\phi = (1.732)(86.67\text{ A}) = \mathbf{150.11\text{ A}}$

f. $E_\phi = \mathbf{120.1\text{ V}}$

17. a. $$\mathbf{I}_{ab} = \frac{\mathbf{V}_{ab}}{\mathbf{Z}_{ab}} = \frac{16\text{ kV }\angle 0°}{300\ \Omega + j1000\ \Omega} = \frac{16\text{ kV }\angle 0°}{1044.03\ \Omega\ \angle 73.30°}$$

$\mathbf{I}_{ab} = \mathbf{15.325\text{ A }\angle -73.30°}$

$$\mathbf{I}_{bc} = \frac{\mathbf{V}_{bc}}{\mathbf{Z}_{bc}} = \frac{16\text{ kV }\angle -120°}{1044.03\ \Omega\ \angle 73.30°} = \mathbf{15.325\text{ A }\angle -193.30°}$$

$$\mathbf{I}_{ca} = \frac{\mathbf{V}_{ca}}{\mathbf{Z}_{ca}} = \frac{16\text{ kV }\angle 120°}{1044.03\ \Omega\ \angle 73.30°} = \mathbf{15.325\text{ A }\angle 46.7°}$$

b. $\mathbf{I}_{Aa} - \mathbf{I}_{ab} + \mathbf{I}_{ca} = 0$

$$\begin{aligned}\mathbf{I}_{Aa} &= \mathbf{I}_{ab} - \mathbf{I}_{ca} = 15.325\text{ A }\angle -73.30° - 15.325\text{ A }\angle 46.7°\\ &= (4.40\text{ A} - j14.68\text{ A}) - (10.51\text{ A} + j11.153\text{ A})\\ &= 4.40\text{ A} - 10.51\text{ A} - j(14.68\text{ A} + 11.153\text{ A})\\ &= -6.11\text{ A} - j25.83\text{ A} = \mathbf{26.54\text{ A }\angle -103.31°}\end{aligned}$$

$\mathbf{I}_{Bb} + \mathbf{I}_{ab} = \mathbf{I}_{bc}$

$$\begin{aligned}\mathbf{I}_{Bb} &= \mathbf{I}_{bc} - \mathbf{I}_{ab} = 15.325\text{ A }\angle -193.30° - 15.325\text{ A }\angle -73.30°\\ &= \mathbf{26.54\text{ A }\angle 136.68°}\end{aligned}$$

$\mathbf{I}_{Cc} + \mathbf{I}_{bc} = \mathbf{I}_{ca}$

$$\begin{aligned}\mathbf{I}_{Cc} &= \mathbf{I}_{ca} - \mathbf{I}_{bc} = 15.325\text{ A }\angle 46.7° - 15.325\text{ A }\angle -193.30°\\ &= \mathbf{26.54\text{ A }\angle 16.69°}\end{aligned}$$

c. $$\begin{aligned}\mathbf{E}_{AB} &= \mathbf{I}_{Aa}(10\ \Omega + j20\ \Omega) + \mathbf{V}_{ab} - \mathbf{I}_{Bb}(22.361\ \Omega\ \angle 63.43°)\\ &= (26.54\text{ A }\angle -103.31°)(22.361\ \Omega\ \angle 63.43°) + 16\text{ kV }\angle 0°\\ &\qquad - (26.54\text{ A }\angle 136.68°)(22.361\ \Omega\ \angle 63.43°)\\ &= (455.41\text{ V} - j380.52\text{ V}) + 16{,}000\text{ V} - (-557.28\text{ V} - j204.04\text{ V})\\ &= 17{,}012.69\text{ V} - j176.48\text{ V}\\ &= \mathbf{17{,}013.6\text{ V }\angle -0.59°}\end{aligned}$$

$$\begin{aligned}\mathbf{E}_{BC} &= \mathbf{I}_{Bb}(22.361\ \Omega\ \angle 63.43°) + \mathbf{V}_{bc} - \mathbf{I}_{Cc}(22.361\ \Omega\ \angle 63.53°)\\ &= (26.54\text{ A }\angle 136.68°)(22.361\ \Omega\ \angle 63.53°) + 16\text{ kV }\angle -120°\\ &\qquad - (26.54\text{ A }\angle 16.69°)(22.361\ \Omega\ \angle 63.53°)\\ &= -8659.07\text{ V} - j14{,}645.44\text{ V}\\ &= \mathbf{17{,}013.77\text{ V }\angle -120.59°}\end{aligned}$$

$$\begin{aligned}
\mathbf{E}_{CA} &= \mathbf{I}_{Cc}(22.361\ \Omega\ \angle 63.43°) + \mathbf{V}_{ca} - \mathbf{I}_{Aa}(22.361\ \Omega\ \angle 63.43°)\\
&= (26.54\text{ A } \angle 16.69°)(22.361\ \Omega\ \angle 63.43°) + 16{,}000\text{ V } \angle +120°\\
&\qquad - (26.54\text{ A } \angle -103.31°)(22.361\ \Omega\ \angle 63.53°)\\
&= -8355.27\text{ V} + j14{,}820.97\text{ V}\\
&= \mathbf{17{,}013.87\ V\ \angle 119.41°}
\end{aligned}$$

19. a. $E_\phi = E_L = \mathbf{208\ V}$ b. $V_\phi = E_L\sqrt{3} = \mathbf{120.09\ V}$

c. $I_\phi = \dfrac{V_\phi}{Z_\phi} = \dfrac{120.09\text{ V}}{16.971\ \Omega} = \mathbf{7.076\ A}$ d. $I_L = I_\phi = \mathbf{7.076\ A}$

21. $V_{an} = V_{bn} = V_{cn} = \dfrac{120\text{ V}}{\sqrt{3}} = \dfrac{120\text{ V}}{1.732} = \mathbf{69.28\ V}$

$I_{an} = I_{bn} = I_{cn} = \dfrac{69.28\text{ V}}{24\ \Omega} = \mathbf{2.89\ A}$

$I_{Aa} = I_{Bb} = I_{Cc} = \mathbf{2.89\ A}$

23. $V_{an} = V_{bn} = V_{cn} = \mathbf{69.28\ V}$

$\mathbf{Z}_\phi = 20\ \Omega\ \angle 0° \parallel 15\ \Omega\ \angle -90° = 12\ \Omega\ \angle -53.13°$

$I_{an} = I_{bn} = I_{cn} = \dfrac{69.28\text{ V}}{12\ \Omega} = \mathbf{5.77\ A}$

$I_{Aa} = I_{Bb} = I_{Cc} = \mathbf{5.77\ A}$

25. a. $E_\phi = E_L = \mathbf{440\ V}$ b. $V_\phi = E_L = \mathbf{440\ V}$

c. $\mathbf{Z}_\phi = 12\ \Omega - j9\ \Omega = 15\ \Omega\ \angle -36.87°$

$I_\phi = \dfrac{V_\phi}{Z_\phi} = \dfrac{440\text{ V}}{15\ \Omega} = \mathbf{29.33\ A}$

d. $I_L = \sqrt{3}\, I_\phi = (1.732)(29.33\text{ A}) = \mathbf{50.8\ A}$

27. a. $\theta_2 = \mathbf{-120°}$, $\theta_3 = \mathbf{+120°}$

b. $\mathbf{V}_{ab} = \mathbf{100\ V\ \angle 0°}$, $\mathbf{V}_{bc} = \mathbf{100\ V\ \angle -120°}$, $\mathbf{V}_{ca} = \mathbf{100\ V\ \angle 120°}$

c. —

d. $\mathbf{I}_{ab} = \dfrac{\mathbf{V}_{ab}}{\mathbf{Z}_{ab}} = \dfrac{100\text{ V } \angle 0°}{20\ \Omega\ \angle 0°} = \mathbf{5\ A\ \angle 0°}$

$\mathbf{I}_{bc} = \dfrac{\mathbf{V}_{bc}}{\mathbf{Z}_{bc}} = \dfrac{100\text{ V } \angle -120°}{20\ \Omega\ \angle 0°} = \mathbf{5\ A\ \angle -120°}$

$\mathbf{I}_{ca} = \dfrac{\mathbf{V}_{ca}}{\mathbf{Z}_{ca}} = \dfrac{100\text{ V } \angle 120°}{20\ \Omega\ \angle 0°} = \mathbf{5\ A\ \angle 120°}$

e. $I_{Aa} = I_{Bb} = I_{Cc} = \sqrt{3}\,(5\text{ A}) = \mathbf{8.66\ A}$

29. a. $\theta_2 = \mathbf{-120°}$, $\theta_3 = \mathbf{120°}$

b. $\mathbf{V}_{ab} = \mathbf{100\ V\ \angle 0°}$, $\mathbf{V}_{bc} = \mathbf{100\ V\ \angle -120°}$, $\mathbf{V}_{ca} = \mathbf{100\ V\ \angle 120°}$

c. —

d. $\mathbf{Z}_\phi = 20\ \Omega\ \angle 0° \parallel 20\ \Omega\ \angle -90° = 14.14\ \Omega\ \angle -45°$

$$\mathbf{I}_{ab} = \frac{100\text{ V } \angle 0°}{14.14\ \Omega\ \angle\text{-}45°} = \mathbf{7.072\ A\ \angle 45°}$$

$$\mathbf{I}_{bc} = \frac{100\text{ V } \angle\text{-}120°}{14.14\ \Omega\ \angle\text{-}45°} = \mathbf{7.072\ A\ \angle -75°}$$

$$\mathbf{I}_{ca} = \frac{100\text{ V } \angle 120°}{14.14\ \Omega\ \angle\text{-}45°} = \mathbf{7.072\ A\ \angle 165°}$$

e. $I_{Aa} = I_{Bb} = I_{Cc} = \left(\sqrt{3}\right)(7.072\text{ A}) = \mathbf{12.25\ A}$

31. $V_\phi = 120\text{ V}$, $I_\phi = 120\text{ V}/20\ \Omega = 6\text{A}$

$P_T = 3I_\phi^2 R_\phi = 3(6\text{ A})^2\ 20\ \Omega = \mathbf{2160\ W}$

$Q_T = \mathbf{0\ VAR}$

$S_T = P_T = \mathbf{2160\ VA}$

$$F_p = \frac{P_T}{S_T} = \frac{2160\text{ W}}{2160\text{ VA}} = \mathbf{1}$$

33. $V_\phi = 208\text{ V}$

$$P_T = 3\left[\frac{V_\phi^2}{R_\phi}\right] = 3\cdot\frac{(208\text{ V})^2}{18\ \Omega} = \mathbf{7210.67\ W}$$

$$Q_T = 3\left[\frac{V_\phi^2}{X_\phi}\right] = 3\cdot\frac{(208\text{ V})^2}{18\ \Omega} = \mathbf{7210.67\ VAR}(\boldsymbol{C})$$

$$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{10{,}197.42\ VA}$$

$$F_p = \frac{P_T}{S_T} = \frac{7210.67\text{ W}}{10{,}197.42\text{ VA}} = \mathbf{0.707\ (leading)}$$

35. $P_T = 3I_\phi^2 R_\phi = 3(15.56\text{ A})^2\ 10\ \Omega = \mathbf{7.263\ kW}$

$Q_T = 3I_\phi^2 X_\phi = 3(15.56\text{ A})^2\ 10\ \Omega = \mathbf{7.263\ kVAR}$

$$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{10.272\ kVA}$$

$$F_p = \frac{P_T}{S_T} = \frac{7.263\text{ kW}}{10.272\text{ kVA}} = \mathbf{0.7071\ (lagging)}$$

37. $\mathbf{Z}_\phi = 10\ \Omega + j20\ \Omega = 22.36\ \Omega\ \angle 63.43°$

$V_\phi = \dfrac{V_L}{\sqrt{3}} = \dfrac{120\text{ V}}{1.732} = 69.28\text{ V}$

$I_\phi = \dfrac{V_\phi}{Z_\phi} = \dfrac{69.28\text{ V}}{22.36\ \Omega} = 3.098\text{ A}$

$P_T = 3I_\phi^2R_\phi = 3(3.098\text{ A})^2\ 10\ \Omega = \mathbf{287.93\ W}$

$Q_T = 3I_\phi^2X_\phi = 3(3.098\text{ A})^2\ 20\ \Omega = \mathbf{575.86\ VAR}$

$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{643.83\ VA}$

$F_p = \dfrac{P_T}{S_T} = \dfrac{287.93\text{ W}}{643.83\text{ VA}} = \mathbf{0.4472\ (lagging)}$

39. $Z_\phi = 12\ \Omega + j16\ \Omega = 20\ \Omega\ \angle 53.13°$

$I_\phi = \dfrac{V_\phi}{Z_\phi} = \dfrac{100\text{ V}}{20\ \Omega} = 5\text{ A}$

$P_T = 3I_\phi^2R_\phi = 3(5\text{ A})^2\ 12\ \Omega = \mathbf{900\ W}$

$Q_T = 3I_\phi^2X_\phi = 3(5\text{ A})^2\ 16\ \Omega = \mathbf{1200\ VAR}(\boldsymbol{L})$

$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{1500\ VA}$

$F_p = \dfrac{P_T}{S_T} = \dfrac{900\text{ W}}{1500\text{ VA}} = \mathbf{0.6\ (lagging)}$

41. $P_T = \sqrt{3}\,E_LI_L\cos\theta$

$1200\text{ W} = \sqrt{3}\,(208\text{ V})I_L(0.6) \Rightarrow I_L = 5.55\text{ A}$

$V_\phi = \dfrac{V_L}{\sqrt{3}} = \dfrac{208\text{ V}}{1.732} = 120.1\text{ V}$

$\theta = \cos^{-1} 0.6 = 53.13°\text{ (leading)}$

$\mathbf{Z}_\phi = \dfrac{\mathbf{V}_\phi}{\mathbf{I}_\phi} = \dfrac{120.1\text{ V}\ \angle 0°}{5.55\text{ A}\ \angle 53.13°} = 21.64\ \Omega\ \angle -53.13° = \underbrace{12.98\ \Omega}_{R} - j\underbrace{17.31\ \Omega}_{X_C}$

43. a. $E_\phi = \dfrac{16\text{ kV}}{\sqrt{3}} = \mathbf{9{,}237.6\ V}$

b. $I_L = I_\phi = \mathbf{80\ A}$

c. $P_{\phi_L} = \dfrac{1200\text{ kW}}{3} = 400\text{ kW}$

$P_{4\Omega} = (80\text{ A})^2 4\ \Omega = 25.6\text{ kW}$

$P_T = 3P_\phi = 3(25.6\text{ kW} + 400\text{ kW}) = \mathbf{1276.8\ kW}$

d. $F_p = \dfrac{P_T}{S_T},\ S_T = \sqrt{3}\,V_LI_L = \sqrt{3}\,(16\text{ kV})(80\text{ A}) = 2{,}217.025\text{ kVA}$

$F_p = \dfrac{1{,}276.8\text{ kW}}{2{,}217.025\text{ kVA}} = \mathbf{0.576\ lagging}$

e. $\theta_L = \cos^{-1} 0.576 = 54.83°$ (lagging)

$$\mathbf{I}_{Aa} = \frac{\mathbf{E}_{AN}\angle 0°}{\underset{\substack{\uparrow \\ \text{for entire load}}}{Z_T \angle 54.83°}} \Rightarrow \underbrace{80\text{ A}}_{\text{given}} \angle -54.83°$$

f.
$$\begin{aligned}
\mathbf{V}_{an} &= \mathbf{E}_{AN} - \mathbf{I}_{Aa}(4\ \Omega + j20\ \Omega) \\
&= 9237.6\text{ V} \angle 0° - (80\text{ A} \angle -54.83°)(20.396\ \Omega \angle 78.69°) \\
&= 9237.6\text{ V} \angle 0° - 1631.68\text{ V} \angle 23.86° \\
&= 9237.6\text{ V} - (1492.22\text{ V} + j660\text{ V}) \\
&= 7745.38\text{ V} - j660\text{ V} \\
&= \mathbf{7773.45\ V \angle -4.87°}
\end{aligned}$$

g.
$$\begin{aligned}
\mathbf{Z}_\phi &= \frac{\mathbf{V}_{an}}{\mathbf{I}_{Aa}} = \frac{7773.45\text{ V} \angle -4.87°}{80\text{ A} \angle -54.83°} = 97.168\ \Omega \angle 49.95° \\
&= \underbrace{62.52\ \Omega}_{R} + j\underbrace{74.38\ \Omega}_{X_L}
\end{aligned}$$

h. F_p(entire load) = **0.576 (lagging)**
F_p(load) = **0.643 (lagging)**

i.
$$\eta = \frac{P_o}{P_i} = \frac{P_i - P_{\text{lost}}}{P_i} = \frac{1276.8\text{ kW} - 3(25.6\text{ kW})}{1276.8\text{ kW}} = 0.9398 \Rightarrow \mathbf{93.98\%}$$

45. b. $P_T =$ **5899.64 W**, $P_{\text{meter}} =$ **1966.55 W**

49. a.
$$V_\phi = E_\phi = \frac{E_L}{\sqrt{3}} = \mathbf{120.09\ V}$$

b.
$$\begin{aligned}
I_{an} &= \frac{V_{an}}{Z_{an}} = \frac{120.09\text{ V}}{14.142\ \Omega} = \mathbf{8.492\ A} \\
I_{bn} &= \frac{V_{bn}}{Z_{bn}} = \frac{120.09\text{ V}}{16.971\ \Omega} = \mathbf{7.076\ A} \\
I_{cn} &= \frac{V_{cn}}{Z_{cn}} = \frac{120.09\text{ V}}{2.828\ \Omega} = \mathbf{42.465\ A}
\end{aligned}$$

c.
$$\begin{aligned}
P_T &= I_{\text{an}}^2\, 10\ \Omega + I_{\text{bn}}^2\, 12\ \Omega + I_{\text{cn}}^2\, 2\ \Omega \\
&= (8.492\text{ A})^2\, 10\ \Omega + (7.076\text{ A})^2\, 12\ \Omega + (42.465\text{ A})^2\, 2\ \Omega \\
&= 721.141\text{ W} + 600.837\text{ W} + 3606.552\text{ W} \\
&= \mathbf{4928.53\ W}
\end{aligned}$$

$Q_T = P_T =$ **4928.53 VAR(*L*)**

$$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{6969.99\ VA}$$

$$F_p = \frac{P_T}{S_T} = \mathbf{0.7071\ (lagging)}$$

d. $\mathbf{E}_{an} = 120.09\text{ V}\angle -30°$, $\mathbf{E}_{bn} = 120.09\text{ V}\angle -150°$, $\mathbf{E}_{cn} = 120.09\text{ V}\angle 90°$

$$\mathbf{I}_{an} = \frac{\mathbf{E}_{an}}{\mathbf{Z}_{an}} = \frac{120.09\text{ V}\ \angle -30°}{10\ \Omega + j10\ \Omega} = \frac{120.09\text{ V}\ \angle -30°}{14.142\ \Omega\ \angle 45°} = \mathbf{8.492\ A\ \angle -75°}$$

$$\mathbf{I}_{bn} = \frac{\mathbf{E}_{bn}}{\mathbf{Z}_{bn}} = \frac{120.09\text{ V}\ \angle -150°}{12\ \Omega + j12\ \Omega} = \frac{120.09\text{ V}\ \angle -150°}{16.971\ \Omega\ \angle 45°} = \mathbf{7.076\ A\ \angle -195°}$$

$$\mathbf{I}_{cn} = \frac{\mathbf{E}_{cn}}{\mathbf{Z}_{cn}} = \frac{120.09\text{ V}\ \angle 90°}{2\ \Omega + j2\ \Omega} = \frac{120.09\text{ V}\ \angle 90°}{2.828\ \Omega\ \angle 45°} = \mathbf{42.465\ A\ \angle 45°}$$

e.
$$\begin{aligned}\mathbf{I}_N &= \mathbf{I}_{an} + \mathbf{I}_{bn} + \mathbf{I}_{cn}\\ &= 8.492\text{ A}\ \angle -75° + 7.076\text{ A}\ \angle -195° + 42.465\text{ A}\angle 45°\\ &= (2.198\text{ A} - j8.20\text{ A}) + (-6.83\text{ A} + j1.83\text{ A}) + (30.03\text{ A} + j30.03\text{ A})\\ &= 25.398\text{ A} - j23.661\text{ A}\\ &= \mathbf{34.712\ A\ \angle -42.972°}\end{aligned}$$

CHAPTER 22 (Even)

2. a. $E_\phi = E_L/\sqrt{3} = 208\text{ V}/1.732 = \mathbf{120.1\text{ V}}$

   b. $V_\phi = E_\phi = \mathbf{120.1\text{ V}}$

   c. $\mathbf{Z}_\phi = 12\ \Omega - j16\ \Omega = 20\ \Omega\ \angle -53.13°$

   $$I_\phi = \frac{V_\phi}{Z_\phi} = \frac{120.1\text{ V}}{20\ \Omega} \cong \mathbf{6\text{ A}}$$

   d. $I_L = I_\phi = \mathbf{6\text{ A}}$

4. a. $\theta_2 = \mathbf{-120°}$, $\theta_3 = \mathbf{120°}$

   b. $\mathbf{V}_{an} = \mathbf{120\text{ V}\ \angle 0°}$, $\mathbf{V}_{bn} = \mathbf{120\text{ V}\ \angle -120°}$, $\mathbf{V}_{cn} = \mathbf{120\text{ V}\ \angle 120°}$

   c. $$\mathbf{I}_{\text{an}} = \frac{\mathbf{V}_{an}}{\mathbf{Z}_{an}} = \frac{120\text{ V}\ \angle 0°}{20\ \Omega\ \angle 0°} = \mathbf{6\text{ A}\ \angle 0°}$$

   $$\mathbf{I}_{\text{bn}} = \frac{\mathbf{V}_{bn}}{\mathbf{Z}_{bn}} = \frac{120\text{ V}\ \angle -120°}{20\ \Omega\ \angle 0°} = \mathbf{6\text{ A}\ \angle -120°}$$

   $$\mathbf{I}_{\text{cn}} = \frac{\mathbf{V}_{cn}}{\mathbf{Z}_{cn}} = \frac{120\text{ V}\ \angle 120°}{20\ \Omega\ \angle 0°} = \mathbf{6\text{ A}\ \angle 120°}$$

   d. $I_L = I_\phi = \mathbf{6A}$

   e. $V_L = \sqrt{3}\,V_\phi = \sqrt{3}\,(120\text{ V}) = \mathbf{207.8\text{ V}}$

6. a, b. The same as problem 4.

   c. $\mathbf{Z}_\phi = 6\ \Omega\ \angle 0° \,\|\, 8\ \Omega\ \angle -90° = 4.8\ \Omega\ \angle -36.87°$

   $$\mathbf{I}_{an} = \frac{\mathbf{V}_{an}}{\mathbf{Z}_{an}} = \frac{120\text{ V}\ \angle 0°}{4.8\ \Omega\ \angle -36.87°} = \mathbf{25\text{ A}\ \angle 36.87°}$$

   $$\mathbf{I}_{bn} = \frac{\mathbf{V}_{bn}}{\mathbf{Z}_{bn}} = \frac{120\text{ V}\ \angle -120°}{4.8\ \Omega\ \angle -36.87°} = \mathbf{25\text{ A}\ \angle -83.13°}$$

   $$\mathbf{I}_{cn} = \frac{\mathbf{V}_{cn}}{\mathbf{Z}_{cn}} = \frac{120\text{ V}\ \angle 120°}{4.8\ \Omega\ \angle -36.87°} = \mathbf{25\text{ A}\ \angle 156.87°}$$

   d. $I_L = I_\phi = \mathbf{25\text{ A}}$

   e. $V_L = \sqrt{3}\,V_\phi = \sqrt{3}\,(120\text{ V}) = \mathbf{207.84\text{ V}}$

8. $\mathbf{Z}_\phi = 12\ \Omega + j16\ \Omega = 20\ \Omega \angle 53.13°$

   $$I_\phi = \frac{V_\phi}{Z_\phi} = \frac{50\text{ V}}{20\ \Omega} = \mathbf{2.5\text{ A}}$$

   $\mathbf{Z}_{T_\phi} = 13\ \Omega + j16\ \Omega = 20.62\ \Omega\ \angle 50.91°$

   $V_\phi = I_\phi Z_{T_\phi} = (2.5\text{ A})(20.62\ \Omega) = 51.55\text{ V}$

   $V_L = \sqrt{3}\,V_\phi = \left(\sqrt{3}\right)(51.55\text{ V}) = \mathbf{89.285\text{ V}}$

10. a. $E_\phi = E_L/\sqrt{3} = 208\text{ V}/1.732 = \mathbf{120.1\text{ V}}$

    b. $V_\phi = E_L = \mathbf{208\text{ V}}$

    c. $$I_\phi = \frac{V_\phi}{Z_\phi} = \frac{208\text{ V}}{20\ \Omega} = \mathbf{10.4\text{ A}}$$

    d. $I_L = \sqrt{3}\,I_\phi = (1.732)(10.4\text{ A}) = \mathbf{18\text{ A}}$

12. $\mathbf{Z}_\phi = 18\ \Omega\ \angle 0° \parallel 18\ \Omega\ \angle -90° = 12.728\ \Omega\ \angle -45°$

a. $E_\phi = V_L/\sqrt{3} = 208\ \text{V}/\sqrt{3} = \mathbf{120.09\ V}$ b. $V_\phi = \mathbf{208\ V}$

c. $I_\phi = \dfrac{V_\phi}{Z_\phi} = \dfrac{208\ \text{V}}{12.728\ \Omega} = \mathbf{16.342\ A}$

d. $I_L = \sqrt{3}\, I_\phi = (1.732)(16.342\ \text{A}) = \mathbf{28.304\ A}$

14. a. $\theta_2 = \mathbf{-120°},\ \theta_3 = \mathbf{+120°}$

b. $\mathbf{V}_{ab} = \mathbf{208\ V\ \angle 0°},\ \mathbf{V}_{bc} = \mathbf{208\ V\ \angle -120°},\ \mathbf{V}_{ca} = \mathbf{208\ V\ \angle 120°}$

c. —

d. $\mathbf{Z}_\phi = 100\ \Omega - j100\ \Omega = 141.42\ \Omega \angle -45°$

$$\mathbf{I}_{ab} = \frac{\mathbf{V}_{ab}}{\mathbf{Z}_{ab}} = \frac{208\ \text{V}\ \angle 0°}{141.42\ \Omega\ \angle -45°} = \mathbf{1.471\ A\ \angle 45°}$$

$$\mathbf{I}_{bc} = \frac{\mathbf{V}_{bc}}{\mathbf{Z}_{bc}} = \frac{208\ \text{V}\ \angle -120°}{141.42\ \Omega\ \angle -45°} = \mathbf{1.471\ A\ \angle -75°}$$

$$\mathbf{I}_{ca} = \frac{\mathbf{V}_{ca}}{\mathbf{Z}_{ca}} = \frac{208\ \text{V}\ \angle 120°}{141.42\ \Omega\ \angle -45°} = \mathbf{1.471\ A\ \angle 165°}$$

e. $I_L = \sqrt{3}\, I_\phi = (1.732)(1.471\ \text{A}) = \mathbf{2.548\ A}$

f. $E_\phi = E_L/\sqrt{3} = 208\ \text{V}/1.732 = \mathbf{120.1\ V}$

16. $V_{ab} = V_{bc} = V_{ca} = \mathbf{220\ V}$

$\mathbf{Z}_\phi = 10\ \Omega + j10\ \Omega = 14.142\ \Omega \angle 45°$

$$I_{ab} = I_{bc} = I_{ca} = \frac{V_\phi}{Z_\phi} = \frac{220\ \text{V}}{14.142\ \Omega} = \mathbf{15.56\ A}$$

18. a. $E_\phi = E_L = \mathbf{208\ V}$ b. $V_\phi = \dfrac{E_L}{\sqrt{3}} = \dfrac{208\ \text{V}}{1.732} = \mathbf{120.1\ V}$

c. $I_\phi = \dfrac{V_\phi}{Z_\phi} = \dfrac{120.1\ \text{V}}{30\ \Omega} = \mathbf{4.003\ A}$ d. $I_L = I_\phi \cong \mathbf{4\ A}$

20. a, b. The same as problem 18.

c. $\mathbf{Z}_\phi = 15\ \Omega\ \angle 0° \parallel 20\ \Omega\ \angle -90° = 12\ \Omega\ \angle -36.87°$

$$I_\phi = \frac{V_\phi}{Z_\phi} = \frac{120.1\ \text{V}}{12\ \Omega} \cong \mathbf{10\ A}$$

d. $I_L = I_\phi \cong \mathbf{10\ A}$

22. $V_{an} = V_{bn} = V_{cn} = \dfrac{120\text{ V}}{\sqrt{3}} = \mathbf{69.28\ V}$

$\mathbf{Z}_\phi = 10\ \Omega + j20\ \Omega = 22.36\ \Omega\angle 63.43°$

$I_{an} = I_{bn} = I_{cn} = \dfrac{\mathbf{V}_\phi}{\mathbf{Z}_\phi} = \dfrac{69.28\text{ V}}{22.36\ \Omega} = \mathbf{3.098\ A}$

$I_{Aa} = I_{Bb} = I_{Cc} = I_\phi = \mathbf{3.098\ A}$

24. a. $E_\phi = E_L = \mathbf{440\ V}$

b. $V_\phi = E_L = E_\phi = \mathbf{440\ V}$

c. $I_\phi = \dfrac{V_\phi}{Z_\phi} = \dfrac{440\text{ V}}{220\ \Omega} = \mathbf{2\ A}$

d. $I_L = \sqrt{3}\,I_\phi = (1.732)(2\text{ A}) = \mathbf{3.464\ A}$

26. a, b. The same as problem 24.

c. $\mathbf{Z}_\phi = 22\ \Omega\ \angle 0° \,\|\, 22\ \Omega\ \angle 90° = 15.56\ \Omega\ \angle 45°$

$I_\phi = \dfrac{V_\phi}{Z_\phi} = \dfrac{440\text{ V}}{15.56\ \Omega} = \mathbf{28.28\ A}$

d. $I_L = \sqrt{3}\,I_\phi = (1.732)(28.28\text{ A}) = \mathbf{48.98\ A}$

28. a. $\boldsymbol{\theta_2 = -120°,\ \theta_3 = +120°}$

b. $\mathbf{V}_{ab} = \mathbf{100\ V\ \angle 0°},\ \mathbf{V}_{bc} = \mathbf{100\ V\ \angle -120°},\ \mathbf{V}_{ca} = \mathbf{100\ V\ \angle 120°}$

c. —

d. $\mathbf{Z}_\phi = 12\ \Omega + j16\ \Omega = 20\ \Omega\ \angle 53.13°$

$\mathbf{I}_{ab} = \dfrac{\mathbf{V}_{ab}}{\mathbf{Z}_{ab}} = \dfrac{100\text{ V}\ \angle 0°}{20\ \Omega\ \angle 53.13°} = \mathbf{5\ A\ \angle -53.13°}$

$\mathbf{I}_{bc} = \dfrac{\mathbf{V}_{bc}}{\mathbf{Z}_{bc}} = \dfrac{100\text{ V}\ \angle -120°}{20\ \Omega\ \angle 53.13°} = \mathbf{5\ A\ \angle -173.13°}$

$\mathbf{I}_{ca} = \dfrac{\mathbf{V}_{ca}}{\mathbf{Z}_{ca}} = \dfrac{100\text{ V}\ \angle 120°}{20\ \Omega\ \angle 53.13°} = \mathbf{5\ A\ \angle 66.87°}$

e. $I_{Aa} = I_{Bb} = I_{Cc} = \sqrt{3}\,I_\phi = (1.732)(5\text{ A}) = \mathbf{8.66\ A}$

30. $P_T = 3I_\phi^2 R_\phi = 3(6\text{ A})^2\ 12\ \Omega = \mathbf{1296\ W}$

$Q_T = 3I_\phi^2 X_\phi = 3(6\text{ A})^2\ 16\ \Omega = \mathbf{1728\ VAR(}\boldsymbol{C}\mathbf{)}$

$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{2160\ VA}$

$F_p = \dfrac{P_T}{S_T} = \dfrac{1296\text{ W}}{2160\text{ VA}} = \mathbf{0.6\ (leading)}$

32. $P_T = 3I_\phi^2 R_\phi = 3(8.98\text{ A})^2\ 10\ \Omega = \mathbf{2419.21\ W}$

$Q_T = 3I_\phi^2 X_\phi = 3(8.98\text{ A})^2\ 10\ \Omega = \mathbf{2419.21\ VAR(}\boldsymbol{C}\mathbf{)}$

$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{3421.28\ VA}$

$$F_p = \frac{P_T}{S_T} = \frac{2419.21 \text{ W}}{3421.28 \text{ VA}} = \mathbf{0.7071 \text{ (leading)}}$$

34. $P_T = 3I_\phi^2 R_\phi = 3(1.471 \text{ A})^2\, 100\ \Omega = \mathbf{649.15\ W}$

$Q_T = 3I_\phi^2 X_\phi = 3(1.471 \text{ A})^2\, 100\ \Omega = \mathbf{649.15\ VAR(\mathit{C})}$

$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{918.04\ VA}$

$$F_p = \frac{P_T}{S_T} = \frac{649.15 \text{ W}}{918.04 \text{ VA}} = \mathbf{0.7071 \text{ (leading)}}$$

36. $$P_T = 3\frac{V_\phi^2}{R_\phi} = \frac{3(120.1 \text{ V})^2}{15\ \Omega} = \mathbf{2884.80\ W}$$

$$Q_T = 3\frac{V_\phi^2}{X_\phi} = \frac{3(120.1 \text{ V})^2}{20\ \Omega} = \mathbf{2163.60\ VAR(\mathit{C})}$$

$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{3605.97\ VA}$

$$F_p = \frac{P_T}{S_T} = \frac{2884.80 \text{ W}}{3605.97 \text{ VA}} = \mathbf{0.8 \text{ (leading)}}$$

38. $$P_T = 3\frac{V_\phi^2}{R_\phi} = \frac{3(440 \text{ V})^2}{22\ \Omega} = \mathbf{26.4\ kW}$$

$Q_T = P_T = \mathbf{26.4\ kVAR(\mathit{L})}$

$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{37.34\ kVA}$

$$F_p = \frac{P_T}{S_T} = \frac{26.4 \text{ kW}}{37.34 \text{ kVA}} = \mathbf{0.707 \text{ (lagging)}}$$

40. $P_T = \sqrt{3}\, E_L I_L \cos\theta$

$4800 \text{ W} = (1.732)(200 \text{ V})I_L\,(0.8)$

$I_L = 17.32 \text{ A}$

$$I_\phi = \frac{I_L}{\sqrt{3}} = \frac{17.32 \text{ A}}{1.732} = 10 \text{ A}$$

$\theta = \cos^{-1} 0.8 = 36.87°$

$$\mathbf{Z}_\phi = \frac{\mathbf{V}_\phi}{\mathbf{I}_\phi} = \frac{200 \text{ V} \angle 0°}{10 \text{ A} \angle -36.87°} = 20\ \Omega \angle 36.87° = \mathbf{16\ \Omega + \mathit{j}12\ \Omega}$$

42. Δ: $\mathbf{Z}_\phi = 15\ \Omega + j20\ \Omega = 25\ \Omega \angle 53.13°$

$$I_\phi = \frac{\mathbf{V}_\phi}{\mathbf{Z}_\phi} = \frac{125 \text{ V}}{25\ \Omega} = 5 \text{ A}$$

$P_T = 3I_\phi^2 R_\phi = 3(5 \text{ A})^2\, 15\ \Omega = \mathbf{1125\ W}$

$Q_T = 3I_\phi^2 X_\phi = 3(5 \text{ A})^2\, 20\ \Omega = \mathbf{1500\ VAR(\mathit{L})}$

Y: $V_\phi = V_L/\sqrt{3} = 125\text{ V}/1.732 = \mathbf{72.17\text{ V}}$

$\mathbf{Z}_\phi = 3\ \Omega - j4\ \Omega = 5\ \Omega\angle -53.13°$

$I_\phi = \dfrac{V_\phi}{Z_\phi} = \dfrac{72.17\text{ V}}{5\ \Omega} = \mathbf{14.43\text{ A}}$

$P_T = 3I_\phi^2 R_\phi = 3(14.43\text{ A})^2\, 3\ \Omega = \mathbf{1874.02\text{ W}}$

$Q_T = 3I_\phi^2 X_\phi = 3(14.43\text{ A})^2\, 4\ \Omega = \mathbf{2498.7\text{ VAR}}$

$P_T = 1125\text{ W} + 1874.02\text{ W} = \mathbf{2999.02\text{ W}}$

$Q_T = 1500\text{ VAR}(L) - 2498.7\text{ VAR}(C) = \mathbf{998.7\text{ VAR}(C)}$

$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{3161\text{ VA}}$

$F_p = \dfrac{P_T}{S_T} = \dfrac{2999.02\text{ W}}{3161\text{ VA}} = \mathbf{0.949\ (leading)}$

44. a. —

b. $V_\phi = \dfrac{220\text{ V}}{\sqrt{3}} = 127.02\text{ V},\ \mathbf{Z}_\phi = 10\ \Omega - j10\ \Omega = 14.14\ \Omega\angle -45°$

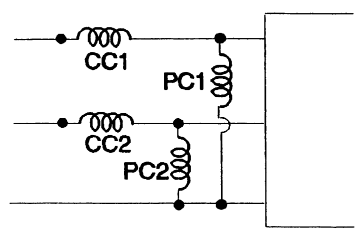
$I_\phi = \dfrac{V_\phi}{Z_\phi} = \dfrac{127.02\text{ V}}{14.14\ \Omega} = 8.98\text{ A}$

$P_T = 3I_\phi^2 R_\phi = 3(8.98\text{ A})^2\, 10\ \Omega = \mathbf{2419.2\text{ W}}$

Each wattmeter: $\dfrac{2419.2\text{ W}}{3} = \mathbf{806.4\text{ W}}$

46. a. —

b. $P_T = P_\ell + P_h = 85\text{ W} + 200\text{ W} = \mathbf{285\text{ W}}$



c. $0.2 \Rightarrow \dfrac{P_\ell}{P_h} = 0.5$

$P_h = \dfrac{P_\ell}{0.5} = \dfrac{100\text{ W}}{0.5} = \mathbf{200\text{ W}}$

$P_T = P_h - P_\ell = 200\text{ W} - 100\text{ W} = \mathbf{100\text{ W}}$

48. a. $\mathbf{I}_{ab} = \dfrac{\mathbf{E}_{AB}}{R\angle 0°} = \dfrac{208\text{ V}\angle 0°}{10\ \Omega\ \angle 0°} = \mathbf{20.8\text{ A}\ \angle 0°}$

$\mathbf{I}_{bc} = \dfrac{\mathbf{E}_{BC}}{R\angle 0°} = \dfrac{208\text{ V}\angle -120°}{10\ \Omega\ \angle 0°} = \mathbf{20.8\text{ A}\ \angle -120°}$

$\mathbf{I}_{ca} = \dfrac{\mathbf{E}_{CA}}{R\angle 0°} = \dfrac{208\text{ V}\angle 120°}{10\ \Omega\ \angle 0°} = \mathbf{20.8\text{ A}\ \angle 120°}$

b. $\mathbf{I}_{Aa} + \mathbf{I}_{ca} - \mathbf{I}_{ab} = 0$

$\mathbf{I}_{Aa} = \mathbf{I}_{ab} - \mathbf{I}_{ca}$

$= 20.8\text{ A}\ \angle 0° - 20.8\text{ A}\ \angle 120°$

$= 20.8\text{ A} - (-10.4\text{ A} + j18.01\text{ A})$

$= 31.2\text{ A} - j18.01\text{ A}$

$= \mathbf{36.02\text{ A}\ \angle -30°}$

$\mathbf{I}_{Bb} + \mathbf{I}_{ab} - \mathbf{I}_{bc} = 0$

$$\mathbf{I}_{Bb} = \mathbf{I}_{bc} - \mathbf{I}_{ab}$$
$$= 20.8\text{ A }\angle -120° - 20.8\text{ A }\angle 0°$$
$$= (-10.4\text{ A} - j18.01\text{ A}) - 20.8\text{ A}$$
$$= -31.2\text{ A} - j18.01\text{ A}$$
$$= \mathbf{36.02\ A\ \angle -150°}$$
$$\mathbf{I}_{Cc} + \mathbf{I}_{bc} - \mathbf{I}_{ca} = 0$$
$$\mathbf{I}_{Cc} = \mathbf{I}_{ca} - \mathbf{I}_{bc}$$
$$= 20.8\text{ A }\angle 120° - 20.8\text{ A }\angle -120°$$
$$= (-10.4\text{ A} + j18.01\text{ A}) - (-10.4\text{ A} - j18.01\text{ A})$$
$$= -10.4\text{ A} + 10.4\text{ A} + j18.01\text{ A} + j18.01\text{ A}$$
$$= \mathbf{32.02\ A\ \angle 90°}$$

c. $P_1 = V_{ac}I_{Aa}\cos_{\mathbf{I}_{Aa}}^{\mathbf{V}_{ca}}$, $\quad \mathbf{V}_{ac} = V_{ca}\ \angle\ \theta - 180° = 208\text{ V }\angle 120° - 180°$
$$= 208\text{ V }\angle -60°$$
$$\mathbf{I}_{Aa} = 36.02\text{ A }\angle -30°$$
$$= (208\text{ V})(36.02\text{ A})\cos 30°$$
$$= \mathbf{6488.4\ W}$$

$P_2 = V_{bc}I_{Bb}\cos_{\mathbf{I}_{Bb}}^{\mathbf{V}_{bc}}$, $\quad \mathbf{V}_{bc} = 208\text{ V }\angle -120°,\ \mathbf{I}_{Bb} = 36.02\text{ A }\angle -150°$
$$= (208\text{ V})(36.02\text{ A})\cos 30°$$
$$= \mathbf{6488.4\ W}$$

d. $P_T = P_1 + P_2 = 6488.4\text{ W} + 6488.4\text{ W}$
$$= \mathbf{12{,}976.8\ W}$$

50. $\mathbf{Z}_1 = 12\ \Omega - j16\ \Omega = 20\ \Omega\ \angle -53.13°,\ \mathbf{Z}_2 = 3\ \Omega + j4\ \Omega = 5\ \Omega\ \angle 53.13°$
$\mathbf{Z}_3 = 20\ \Omega\ \angle 0°$

$\mathbf{E}_{AB} = 200\text{ V}\angle 0°,\ \mathbf{E}_{BC} = 200\text{ V }\angle -120°,\ \mathbf{E}_{CA} = 200\text{ V }\angle 120°$
$$\mathbf{Z}_\Delta = \mathbf{Z}_1\mathbf{Z}_2 + \mathbf{Z}_1\mathbf{Z}_3 + \mathbf{Z}_2\mathbf{Z}_3$$
$$= (20\ \Omega\ \angle -53.13°)(5\ \Omega\ \angle 53.13°) + (20\ \Omega\ \angle -53.13°)(20\ \Omega\ \angle 0°) + (5\ \Omega\ \angle 53.13°)(20\ \Omega\ \angle 0°)$$
$$= 100\ \Omega\ \angle 0° + 400\ \Omega\ \angle -53.13° + 100\ \Omega\ \angle 53.13°$$
$$= 100\ \Omega + (240\ \Omega - j320\ \Omega) + (60\ \Omega + j80\ \Omega)$$
$$= 400\ \Omega - j240\ \Omega$$
$$= 466.48\ \Omega\ \angle -30.96°$$
$$\mathbf{I}_{an} = \frac{\mathbf{E}_{AB}\mathbf{Z}_3 - \mathbf{E}_{CA}\mathbf{Z}_2}{\mathbf{Z}_\Delta} = \frac{(200\text{ V }\angle 0°)(20\ \Omega\ \angle 0°) - (200\text{ V }\angle 120°)(5\ \Omega\ \angle 53.13°)}{\mathbf{Z}_\Delta}$$
$$= \frac{4000\text{ A }\angle 0° - 1000\text{ A }\angle 173.13°}{466.48\ \angle -30.96°} = \mathbf{10.706\ A\ \angle 29.59°}$$
$$\mathbf{I}_{bn} = \frac{\mathbf{E}_{BC}\mathbf{Z}_1 - \mathbf{E}_{AB}\mathbf{Z}_3}{\mathbf{Z}_\Delta} = \frac{(200\text{ V }\angle -120°)(20\ \Omega\ \angle -53.13°) - (200\text{ V }\angle 0°)(20\ \Omega\ \angle 0°)}{\mathbf{Z}_\Delta}$$
$$= \frac{4000\text{ A }\angle -173.13° - 4000\text{ A }\angle 0°}{466.48\ \angle -30.96°} = \mathbf{17.12\ A\ \angle\ -145.61°}$$
$$\mathbf{I}_{cn} = \frac{\mathbf{E}_{CA}\mathbf{Z}_2 - \mathbf{E}_{BC}\mathbf{Z}_1}{\mathbf{Z}_\Delta} = \frac{(200\text{ V}\angle 120°)(5\ \Omega\angle 53.13°) - (200\text{ V}\angle -120°)(20\ \Omega\angle -53.13°)}{\mathbf{Z}_\Delta}$$
$$= \frac{1000\text{ A }\angle 173.13° - 4000\text{ A }\angle -173.13°}{466.48\ \angle -30.96°} = \mathbf{6.512\ A\ \angle\ 42.32°}$$

$$
\begin{aligned}
P_T &= I_{\text{an}}^2\ 12\ \Omega + I_{\text{bn}}^2\ 3\ \Omega + I_{\text{cn}}^2\ 20\ \Omega \\
&= (10.706\ \text{A})^2\ 12\ \Omega + (17.119\ \text{A})^2\ 3\ \Omega + (6.512\ \text{A})^2\ 20\ \Omega \\
&= 1375.42\ \text{W} + 879.18\ \text{W} + 848.12\ \text{W} = \mathbf{3102.72\ W}
\end{aligned}
$$

$$
\begin{aligned}
Q_T &= I_{\text{an}}^2 X_C + I_{\text{bn}}^2 X_L = (10.706\ \text{A})^2\ 16\ \Omega + (17.119\ \text{A})^2\ 4\ \Omega \\
&= \underset{(C)}{1833.9\ \text{VAR}} + \underset{(L)}{1172.24\ \text{VAR}} = \underset{(C)}{661.66\ \text{VAR}}
\end{aligned}
$$

$$
S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{3172.49\ VA}
$$

$$
F_p = \frac{P_T}{S_T} = \frac{3102.72\ \text{W}}{3172.49\ \text{VA}} = \mathbf{0.978\ (leading)}
$$